***Influence of Full and Reduced RDF Levels Combined with Nano Diammonium Phosphate on Growth and Nutrient Dynamics in Chickpea (Cicer arietinum)***

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***Abstract***

This study investigated the effects of combining full and reduced recommended dose of fertilizer (RDF) levels with Nano Diammonium Phosphate (DAP) on growth, yield, and nutrient dynamics in chickpea (*Cicer arietinum*). A two-year field experiment was conducted using a randomized block design with 10 treatments and 3 replications. Treatments included the control, 100% RDF, 75% and 50% RDF, and combinations of these with Nano DAP seed treatments and foliar sprays. Key parameters measured included plant growth, yield components, seed and straw yields, nutrient content and uptake, The 100% RDF treatment produced the highest seed yield (15.98 q $ha^{-1}$), followed by 75% RDF + Nano DAP (13.73 q $ha^{-1}$). Nano DAP treatments increased yields compared to equivalent RDF levels alone. The 100% RDF treatment also resulted in maximum nutrient content and uptake in seeds and straw. While Nano DAP improved nutrient use efficiency compared to conventional fertilizers, it did not match the performance of 100% RDF when combined with reduced fertilizer levels. The study demonstrated Nano DAP can partially substitute for conventional fertilizers in chickpea, but cannot fully replace RDF for achieving maximum productivity and nutrient uptake.


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**Keywords:** chickpea, Nano fertilizer, Diammonium Phosphate, nutrient use efficiency, yield and nutrient uptake.


***Introduction***

Chickpea (*Cicer arietinum L.*) is an important pulse crop grown and consumed worldwide. It is a significant source of protein in human diets, especially in developing countries. India is the world's largest producer of chickpea, accounting for approximately 70% of global production [1]. However, chickpea yields in India remain below global averages due to various constraints, including nutrient deficiencies [2]. Balanced fertilization is crucial for achieving optimal chickpea yields. The crop has high phosphorus (P) requirements, especially during early growth stages [3]. Diammonium phosphate (DAP) is a commonly used phosphatic fertilizer for chickpea cultivation. However, conventional fertilizers often have low nutrient use efficiency, with a significant portion being lost to the environment [4]. This leads to economic losses for farmers and potential environmental issues. Nanotechnology offers promising solutions to improve nutrient use efficiency in agriculture [5]. Nano fertilizers, with particle sizes between 1-100 nm, have unique properties that can enhance nutrient availability and uptake by plants [6]. Nano Diammonium phosphate (Nano DAP) has shown potential to improve crop growth and yields while reducing fertilizer application rates in various crops [7, 8]. However, limited research has been conducted on the effects of Nano DAP on chickpea, especially in combination with reduced levels of conventional fertilizers.

***Material and method***

***Experimental site***

The field experiment was conducted during the Rabi (winter) seasons of 2021-22 and 2022-23 at the Pulse Research Unit, Wasim Road Farm, under the auspices of Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV) in Akola, Maharashtra, India (20°42′ N, 77°02′ E, and an altitude of 307.41 meters above mean sea level). The study region experiences a moderate winter climate with cool temperatures, though not severely cold. Historical climatic data indicate that Akola receives an annual average rainfall of approximately 830 mm over 41 rainy days, based on a 40-year record. During the 2021-22 cropping period (October to February), the area received 117 mm of precipitation, slightly above the 40-year average of 106.5 mm for this season.

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The soil at the experimental site is classified as medium-deep black "Vertisols" with a clayey texture, mildly alkaline in reaction, and containing low to moderate levels of soil organic carbon (SOC) and key nutrients, notably nitrogen (N) and phosphorus (P). A randomized block design (RBD) with 10 treatments replicated three times was adopted for this experiment. Each experimental plot measured 3.6 m × 3.0 m, and the chickpea variety 'Kanak' was selected as the test crop. The experiment involved 10 treatments and detail of treatments are given as $T_1$: Absolute control (No NPK), $T_2$: 100% NPK (University recommended practice), $T_3$: 75% Recommended NP + Recommended K, $T_4$: 50% Recommended NP + Recommended K, $T_5$: $T_1$ + Seed treatment with Nano DAP @ 2.5 ml $kg^{-1}$ seed + Foliar supply with Nano DAP @ 2 ml $L^{-1}$ of water at 30 DAS, $T_6$: $T_1$ + Seed treatment with Nano DAP @ 5.0 ml $kg^{-1}$ seed + Foliar supply with Nano DAP @ 2 ml $L^{-1}$ of water at 30 DAS, $T_7$: $T_4$+ Seed treatment with Nano DAP @ 2.5 ml $kg^{-1}$ seed + Foliar supply with Nano DAP @ 2 ml $L^{-1}$ of water at 30 DAS, $T_8$: $T_4$ + Seed treatment with Nano DAP 50 ml $kg^{-1}$ seed + Foliar supply with Nano DAP @ 2 ml $L^{-1}$ of water at 30 DAS, $T_9$: $T_3$ + Seed treatment with Nano DAP @ 2.5 ml $kg^{-1}$ seed + Foliar supply with Nano DAP @ 2 ml $L^{-1}$ of water at 30 DAS, $T_{10}$: $T_3$ + Seed treatment with Nano DAP @ 5.0 ml $kg^{-1}$ seed + Foliar supply with Nano DAP @ 2 ml $L^{-1}$ of water at 30 DAS. The standard recommended dose of fertilizers (RDF) used was 25:50:30 kg NPK per hectare. Nutrient sources included urea for nitrogen, Diammonium Phosphate (DAP) for phosphorus, and muriate of potash (MOP) for potassium. The Nano DAP product applied was commercially sourced and comprised 4% nitrogen and 8.5% $P_2O_5$. Pre-sowing soil preparation involved plowing and harrowing, with sowing executed using a drill method at a row spacing of 30 cm and a seed

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rate of 75-100 kg $ha^{-1}$. Fertilizer applications were made as basal doses in alignment with the treatment specifications at sowing time. Nano DAP seed treatments were administered by immersing seeds in Nano DAP solutions for 15 minutes before sowing. Additionally, a foliar spray of Nano DAP was conducted 30 days post-sowing (DAS) as per the treatment plans. The crop received irrigations according to its water requirements, and manual weeding was performed twice during the growth period. Plant protection protocols were followed as needed based on standard agricultural practices. The crop was harvested upon reaching physiological maturity, concluding the experiment.

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Dry seed treatment / wet ?

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***Result and discussion***

***Number of Branches***

The number of branches $plant^{-1}$ in chickpeas as influenced by different treatments are graphically depicted in Fig 1. The application of 100% RDF recorded highest number of branches $plant^{-1}$ in chickpea at harvest was 7.0 during first year and 7.15 during second year, respectively, which was followed by $T_{10,}$ where reduction of 25% fertilizer dose of NP + recommended K along with seed treatment of Nano DAP @ 5 ml $kg^{-1}$ of seed and foliar spray of Nano DAP @ 2 ml $L^{-1}$ at 30 DAS. The application of 100% RDF recorded highest mean number of branches $plant^{-1}$ in chickpea (7.08), which was followed by $T_{10,}$ The application of 100 per cent recommended dose of fertilizer to chickpea registered significantly higher number of branches $plant^{-1}$ than application of 75 per cent recommended dose of fertilizer along with seed treatment of 5.0 ml $kg^{-1}$ of seed and foliar spray of Nano DAP @ 2 ml $L^{-1}$ at all the crop growth stages during both the years. Lowest number of branches $plant^{-1}$ was observed in absolute control, where no fertilizer applied to chickpea at all the stages of observations during both the years. This was mainly due to an increase in the application of nutrients, which could be due to the enhanced availability of essential elements that promote lateral branching and overall plant growth. When the plant receives enough nutrients, such as nitrogen and phosphorus, it can divert its energy and resources towards the production and growth of lateral shoots, giving it the means to produce more branches. Also, 100% RDF provides more balanced nutrients in the desired proportions for plant growth. In contrast, Nano DAP may lack certain essential nutrients or have limitations in nutrient availability, which can restrict its effectiveness in promoting branch development. Similar promotive effects of fertilizer on the number of branches have also been reported by Hama *et al.* (2017), Namvar *et al.* (2011), Singh *et al.* (1994) and Jat and Mali (1992).

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***Seed Yield per Plant***

Effect of 100% RDF and Nano DAP on seed yield (g $plant^{-1}$) of chickpea was found statistically significant and illustrated in fig. 2 during both years of experimentation. Data indicated that, the seed yield (g plant$^{-1}$) in Rabi chickpea was significantly influenced by the application of different concentrations of N, P and Nano DAP during both years. The application of 100 per cent recommended dose of fertilizer to chickpea showed significantly higher maximum seed yield (6.24 and 6.89 g plant$^{-1}$) in chickpea than the rest of the treatments during both years. However, it was followed by $T_{10}$ (5.52 and 5.73 g plant$^{-1}$), where the application of 75 per cent of the recommended dose of fertilizer along with seed treatment of Nano DAP @ 5.0 ml kg$^{-1}$ of seed and foliar spray of Nano DAP @ 2.0 ml L$^{-1}$ during both years. The control treatment recorded significantly lower seed yield (2.51 and 2.78 g plant$^{-1}$) during both years.

The application of 100% NPK showed highest mean seed yield (6.57 g plant$^{-1}$), which was followed by $T_{10}$, $T_9$, $T_8$, $T_7$, $T_6$, $T_5$, $T_4$ and $T_3$. While lowest seed yield (2.65 g plant$^{-1}$) observed in absolute control ($T_1$), where no fertilizer was applied. Thus when compared mean seed yield (g plant$^{-1}$) under application of 100% recommended dose of fertilizer ($T_2$) significantly improved it by 16.69% over 75 per cent of the recommended dose of fertilizer along with seed treatment of Nano DAP @ 5.0 ml kg$^{-1}$ of seed and foliar spray of Nano DAP @ 2.0 ml L$^{-1}$. This could be due to the increased application of nutrient dosages, along with atmospheric nitrogen fixation, accelerates the assimilation and translocation of photosynthate towards reproductive organs. Similar result were reported by Navghare *et al.* (2023), Rashid *et al*. (2013), Hussen *et al*. (2015) and Tripathi *et al*. (2013).

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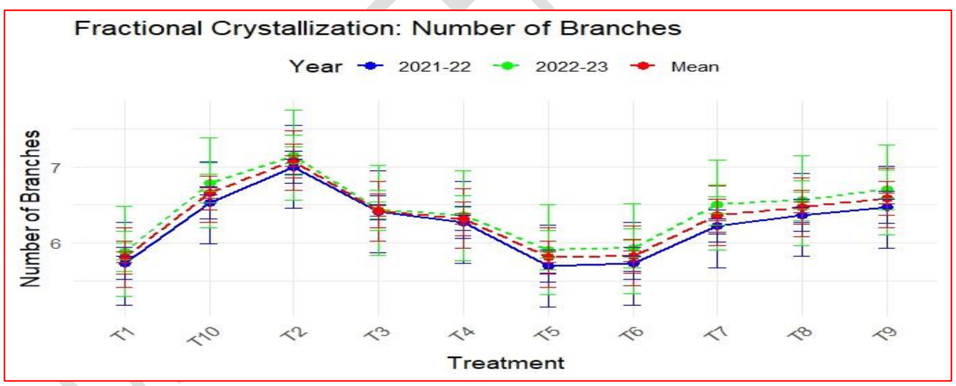


*Fig1. Effect of RDF and Nano Diammonium Phosphate on number of branches plant$^{-1}$*

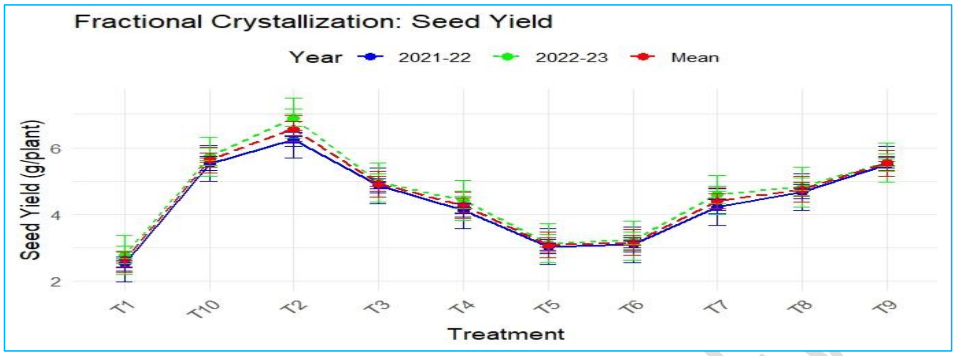


*Fig 2. Effect of RDF and Nano Diammonium Phosphate on seed yield (g/plant$^{-1}$)*

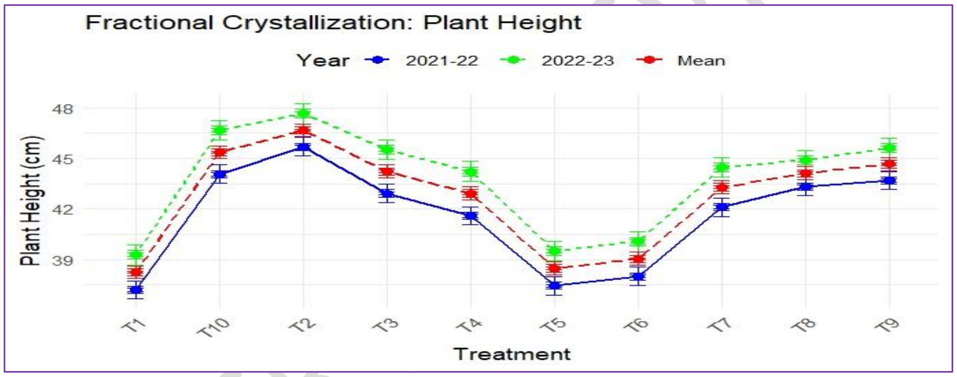


*Fig 3. Effect of RDF and Nano Diammonium Phosphate on plant height (cm)*

***Plant Height***

Plant height at flowering stage was significantly influenced by the treatments in both years. The highest plant height was recorded with 100% RDF ($T_2$) 45.70 cm in 2021-22 and 47.65 cm in 2022-23. This was followed by $T_{10}$ (75% RDF + Nano DAP seed treatment @ 5 ml kg$^{-1}$ + foliar spray @ 2 ml L$^{-1}$) with 44.07 cm and 46.67 cm in the two years respectively. The control treatment (T)) resulted in the lowest plant height. Nano DAP treatments increased plant height compared to equivalent RDF levels alone, but did not match the 100 RDF.

The plant height of chickpea was significantly influenced by the effects of 100% RDF and Nano DAP as mentioned in fig 3 during both year of experimentation.

Among the various treatments, the application of 100 % NPK recorded the significantly highest plant height (45.70 cm and 47.65 cm) in chickpea in both the years of experimentation, it was followed by $T_{10}$, $T_9$, $T_8$, $T_7$, $T_6$, $T_5$, $T_4$, $T_3$ and $T_1$. However, the application of 100 % NPK observed the

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significantly highest mean plant height at (46.68 cm) and it was followed by the application of 75% NP + 100% K+ Nano DAP (ST @ 5 ml $kg^{-1}$ seed & FS @ 0.2 % at 30 DAS). The significantly lowest plant height was found in absolute control.

On the two year mean basis, result indicated that, the application of 100% RDF ($T_2$) recorded significantly highest mean plant height of chickpea at harvest was (46.68 cm), which was followed by $T_{10}$ (45.37 cm), where the application of 75 per cent recommended dose of fertilizer along with seed treatment of 5.0 ml $kg^{-1}$ of seed and foliar spray of Nano DAP @ 2 ml $L^{-1}$. The significant increase of plant height of chickpea with the application of 100% NPK might be due to the application of different rates of N and P nutrients, which can lead to a higher plant height due to improved nutrient availability for the plant. When essential nutrients were provided in sufficient quantities, the plant exhibited increased growth and development, including the elongation of stems and an overall taller stature. This enhanced nutrient supply supports greater cell division and expansion, promoting the upward growth of the plant, which ultimately results in increased plant height. The experimental results aligned with the observations made by Abbasi *et al.*, (2013), which showed a significant impact on plant height when using a nitrogen rate at 75 kg $ha^{-1}$. These results are also in accordance with Tripathi *et al.* (2013) and Namvar *et al.* (2011).

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***Nitrogen Uptake***

The significant increment in respect of total uptake was observed in application of 100 per cent recommended dose of fertilizer ($T_2$) by 144% and 139% over control ($T_1$). Also $T_2$ showed significant increment by 19% and 15% compared to $T_{10}$ (75% NP + recommended K along with Nano DAP at different concentration). The application of 100% NPK fertilizer in the root rhizosphere increased the availability of these nutrients which in turn increased uptake of nitrogen and being pulse crop, it fix the atmospheric nitrogen which fulfill the requirement of nitrogen resulted in higher uptake of nitrogen. These findings were consistent with the results reported in earlier studies by Chavan *et al.* (2008), Gadhia *et al.* (2009), Singh and Rai (2003), and Arbad and Ismail (2011). Also, the application of Nano DAP and 75% RDF had demonstrated high nutrient uptake, but when compared to 100% RDF, it recorded lower nutrient uptake. This was due to the larger particle size of Nano DAP, which resulted in a reduced surface area. Due to the larger particle size, there was less contact between nutrients and the soil, leading to a lower availability of nutrients to the plants. Additionally, Nano DAP contained less nitrogen content, as per references. These results were in conformity with the findings of Xiong *et al.* (2018) and Kopittke *et al.* (2019).

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***Phosphorus Uptake***

Phosphorus uptake showed trends similar to N uptake. Maximum P uptake was observed with 100% RDF (15.84 kg ha$^{-1}$ and 18.12 kg ha$^{-1}$ in 2021-22 and 2022-23 respectively), followed by $T_{10}$. Nano DAP treatments improved P uptake compared to reduced RDF levels alone, but were not as effective as full RDF. The higher dose of phosphorus (100% RDF) was applied as basal dose and irrigation was applied in regular interval directly in root rhizosphere which maintain the soil moisture at field capacity for longer period leads to increase the availability of phosphorus and thereby increase the uptake. These results were consistent with the findings reported by Saleem *et al.* (2010), Win *et al.* (2010), Arbad and Ismail (2011), and Ayyadurai and Manickas (2014). The application of Nano DAP and 75% RDF had shown high phosphorus uptake, but compared to 100% RDF, it recorded lower nutrient uptake. This was due to the larger particle size of the fertilizer. Due to the larger particle size, the surface area was less, resulting in fewer nutrient contacts with the soil and consequently, less nutrient availability to the plants. Moreover, another contributing factor to the reduced nutrient uptake in the 75% NP and 100% K treatment could be the slower release of nutrients from the larger particles, leading to a diminished rate of nutrient absorption by the plants. These results were supported with the findings reported by Tarafdar *et al.* (2012), Xiong *et al.* (2018) and Kopittke *et al.* (2019).

***Potassium Uptake***

Potassium uptake was also significantly affected by the treatments. The highest K uptake was observed with 100% RDF (43.72 kg ha$^{-1}$ and 48.79 kg ha$^{-1}$ in 2021-22 and 2022-23 respectively), followed by $T_{10}$. The control treatment had the lowest K uptake. Nano DAP treatments increased K uptake compared to equivalent RDF levels alone, but did not match the full RDF treatment. The significant increment in total uptake (seed and straw) was observed in the application of 100% recommended dose of fertilizer ($T_2$) and ($T_{10}$) by 159% and 126%, compared to control ($T_1$). These findings align with researched by Dhansil *et al*. (2018), Bharambe and Tomar (2004), and Navale *et al*. (2000).

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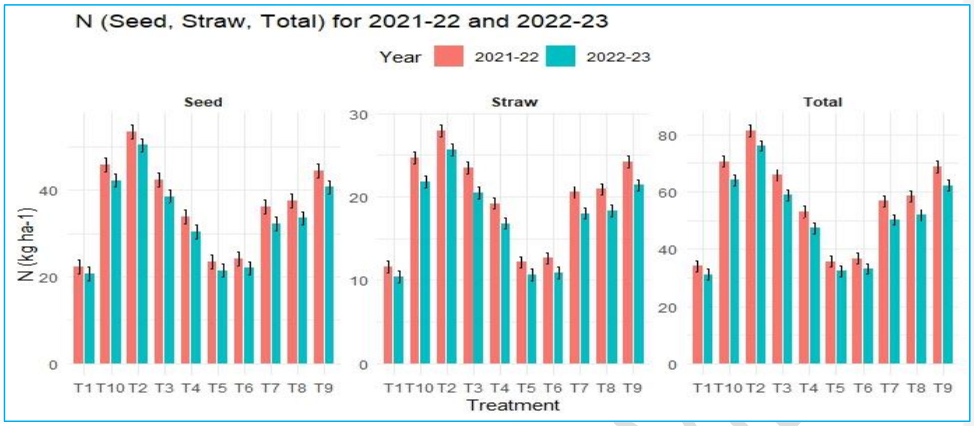


*Fig 4. Influence of RDF and Nano DAP on nitrogen uptake by chickpea during 2021-22 to 2022-23*

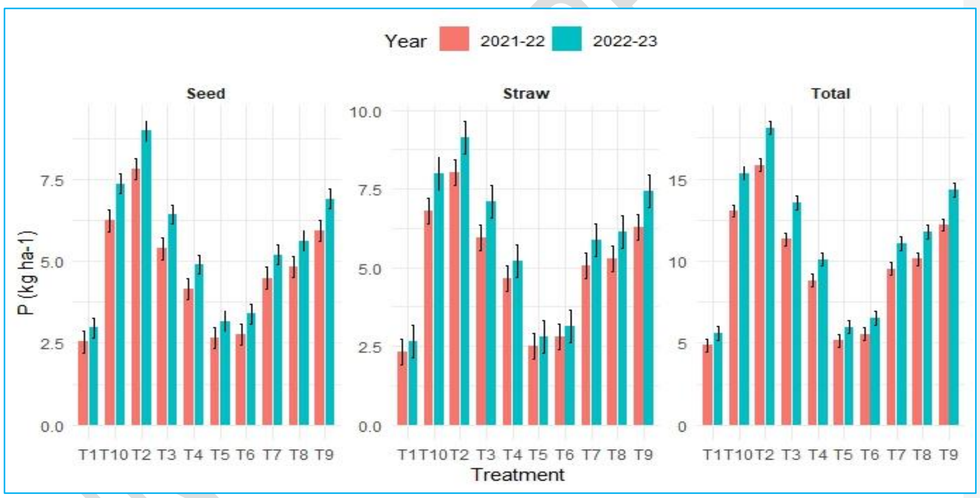


*Fig 5. Influence of RDF and Nano DAP on phosphorous uptake by chickpea during 2021-22 to 2022-23*

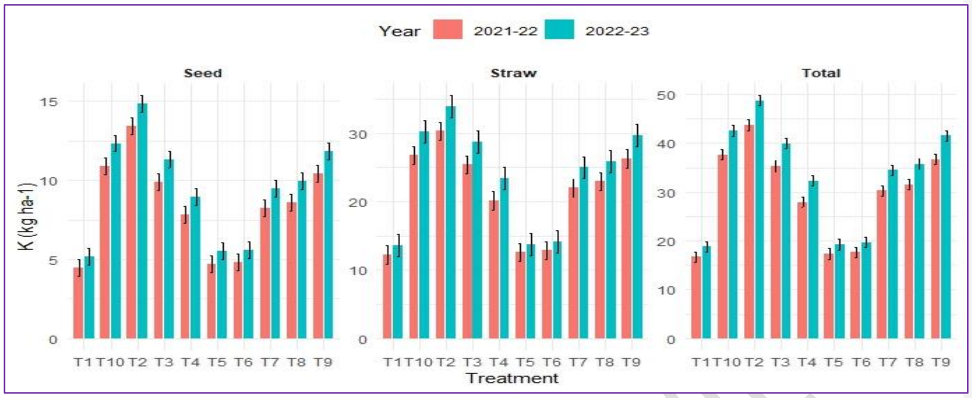


*Fig 6. Influence of RDF and Nano DAP on potassium uptake by chickpea during 2021-22 to 2022-23*

*Table 1 : **Correlation between growth attribute and nutrient uptake by chickpea***

| | No of branches plant$^{-1}$ | Seed yield (g plant$^{-1}$) | Plant height | Total N | Total P | Total K |
|---|---|---|---|---|---|---|
| No of branches plant$^{-1}$ | 1 | .965** | .999** | .887** | .821** | .865** |
| Seed yield(g plant$^{-1}$) | .965** | 1 | .962** | .959** | .923** | .942** |
| Plant height | .999** | .962** | 1 | .892** | .826** | .872** |
| Total N | .887** | .959** | .892** | 1 | .991** | .998** |
| Total P | .821** | .923** | .826** | .991** | 1 | .993** |
| Total K | .865** | .942** | .872** | .998** | .993** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed).

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Correlation for EXP I/II

The study assessed the correlation between growth characteristics (number of branches, pods, and plant height) and nutrient uptake (total nitrogen, phosphorus, and potassium) in chickpea. The study uncovered highly significant positive relationships between these variables. A strong positive correlation was observed between the number of branches and total nitrogen (r = 0.887**), phosphorus (r = 0.821**), and potassium (r = 0.865**), suggesting that improved nutrient uptake positively influences branching. Likewise, the number of pods showed positive correlations with total nitrogen (r = 0.959**), phosphorus (r = 0.923**), and potassium (r = 0.942**), highlighting the critical role of nutrient availability in pod development and reproductive stage. Plant height was also closely linked to total nitrogen (r = 0.892**), phosphorus (r = 0.826**), and potassium (r = 0.872**), indicating that adequate nutrient uptake supports vertical growth and biomass accumulation. Furthermore, the near-perfect correlations among nutrient parameters, such as total nitrogen and phosphorus (r = 0.991**), indicate their interdependence in facilitating growth and development. Overall, these findings emphasize the crucial role of nutrient uptake in enhancing growth attributes, providing valuable insights for optimizing fertilization practices in chickpea cultivation.

*Table 2 : **Multiple linear regression analysis between growth attributes and nutrient uptake***

| Year | Goal | Total Nutrient uptake | | | |
|---|---|---|---|---|---|
| | Growth Attributes | R | $R^2$ | Adjusted $R^2$ | Std. Error of the Estimate |
| 2022-23 | No of branches plant$^{-1}$ | .996[c] | 0.992 | 0.989 | 0.25853 |
| | Seed yield (g plant$^{-1}$) | .993[a] | 0.987 | 0.982 | 1.22352 |
| | Plant height | .996[a] | 0.993 | 0.990 | 1.67697 |

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A multiple regression analysis was conducted to explore the relationship between growth attributes (number of branches per plant, Seed yield (g plant$^{-1}$), and plant height) and total nutrient uptake in chickpea during the 2022-23 growing season. The model demonstrated strong predictive power, with high R, $R^2$, and adjusted $R^2$ values across all growth attributes, indicating a significant association between these variables and nutrient uptake. The number of branches per plant exhibited the highest correlation with total nutrient uptake (R = 0.996), explaining 99.2% of the variance ($R^2$ = 0.992) with an adjusted $R^2$ of 0.989 and a standard error of 0.25853. Similarly, the Seed yield (g plant$^{-1}$) also showed a strong relationship with total nutrient uptake (R = 0.993), accounting for 98.7% of the variance ($R^2$ = 0.987) with an adjusted $R^2$ of 0.982 and a standard error of 1.22352. Plant height displayed a similarly robust association (R = 0.996), explaining 99.3% of the variance ($R^2$ = 0.993) with an adjusted $R^2$ of 0.990 and a standard error of 1.67697. These results indicate that all three growth attributes are highly predictive of nutrient uptake, with the number of branches per plant showing the most precise fit. The findings emphasize the importance of these growth parameters as indicators of nutrient assimilation efficiency in chickpea, providing valuable insights for enhancing crop productivity through targeted agronomic interventions.

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### *Conclusion*

The application of 100% RDF consistently resulted in the highest plant height, number of branches, seed yield per plant, and overall seed yield across two years, demonstrating its effectiveness in maximizing chickpea productivity. Nano DAP treatments, particularly $T_{10}$ (75% RDF + Nano DAP), enhanced growth parameters and seed yield compared to equivalent reduced RDF levels, indicating its potential as a partial substitute for traditional fertilizers, though it could not fully match the performance of 100% RDF. Total nutrient uptake (N, P, and K) was also highest with 100% RDF due to better nutrient availability and uptake efficiency, while Nano DAP combined with reduced RDF improved uptake compared to standalone reduced RDF. Additionally, Nano DAP treatments enhanced nutrient use efficiency (NUE), with regression analysis showing strong correlations between growth parameters, nutrient uptake, and yield. These findings highlight the importance of balanced fertilization, where full RDF remains essential for optimal results, while Nano DAP offers a sustainable alternative to improve efficiency, reduce fertilizer use, and minimize environmental impact in resource-limited scenarios.

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